

# EIC Comprehensive Chromodynamics Experiment



**Tanja Horn**



# ECCE Principles



<https://www.ecce-eic.org/>

- ECCE plans to address the full range of EIC physics outlined in the NAS study and the Yellow Report, as the EIC Project Detector
- ECCE is centered around an existing 1.5T solenoid and envisions to offer full energy coverage, and an optimized far forward detection region
- ECCE comprises 47 institutions with wide-ranging world-class detector expertise and strong involvement in EIC physics

## Expression of Interest (EOI) for the EIC Collider Detector ("ECCE") Consortium



### Contact persons for this submission:

Or Hen ([hen@mit.edu](mailto:hen@mit.edu))

Tanja Horn ([horn@ua.edu](mailto:horn@ua.edu))

John Lajoie ([lajoie@iastate.edu](mailto:lajoie@iastate.edu))

### Institutions collectively involved in this submission of interest:

AANL/Armenia, Academia Sinica/Taiwan, BGU/Israel, BNL, CU Boulder, CUA, Charles U./Prague, Columbia, FIU, GWU, GSU, IJCLab-Orsay/France, ISU, JLab, Kentucky, LANL, LLNL, Lehigh, MIT, National Cheng Kung University/Taiwan, National Central University/Taiwan, National Taiwan University/Taiwan, National Tsing Hua University/Taiwan, ODU, Ohio University, ORNL, Rice, Rutgers, SBU, TAU/Israel, UConn, UIUC, UNH, UVA, Vanderbilt, Wayne State, and WI/Israel.

### Items of interest for potential equipment cooperation:

The EIC enables an exciting research program which will advance our understanding of the structure of hadronic matter. A state-of-the-art collider detector for the EIC, which is needed to realize its physics program, will be extremely complex. It will require extensive infrastructure, and will need to be integrated into the operation of the accelerator to a very high degree. The technically driven reference schedule for the EIC project is aggressive and presents a significant challenge for an EIC detector to be designed, built, commissioned, and ready to start delivering science when the machine begins to deliver collisions. The substantial resources needed to construct a state-of-the-art detector for the EIC present an additional challenge. Time-tested strategies for addressing such challenges include the reuse of existing infrastructure where suitable and leveraging the hard-won expertise gained through previous successful projects.

The EIC Collider dEtector (ECCE) consortium comprises 36 institutions assembled around the idea of building on the foundation of existing infrastructure available at RHIC IP8 and experimental equipment available there and elsewhere at JLab and RHIC. The consortium includes institutions with wide-ranging world-class detector expertise, strong familiarity with the EIC-suitable characteristics of IP8, and an understanding of the approach to DOE project management. Appropriate use of existing infrastructure will help mitigate several technical and schedule risks of an EIC detector project. The technical expertise in the consortium can build on and extend upon the base provided by existing equipment to provide a complete detector with capabilities mandated by the EIC science requirements as defined by the recent EIC Yellow-Report community effort. The substantial project management experience of the involved institutions provides credible "out of the box" know-how for realizing such a sophisticated detector.

Our working principles in developing this consortium have been:

- To follow the guidance provided by the Yellow Report detector design study.

# 1st ECCE Workshop

11 February 2021  
US/Eastern timezone



Overview

Timetable

Contribution List

Participant List



**Starts** 11 Feb 2021, 09:00

**Ends** 11 Feb 2021, 19:00

US/Eastern



John Lajoie

Or Hen

Tanja Horn

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Our working principles in developing this consortium have been:

- To follow the guidance provided by the Yellow Report detector design study.
- Explore utilization and/or upgrades of existing detectors and infrastructure that would enable EIC science by meeting the Yellow Report performance requirements.

The purpose of this first ECCE Workshop is to explore the development of the ECCE detector concept and begin the preparation for a call for detector proposals from EIC Project Management.

1<sup>st</sup> ECCE Workshop on  
11 February 2021

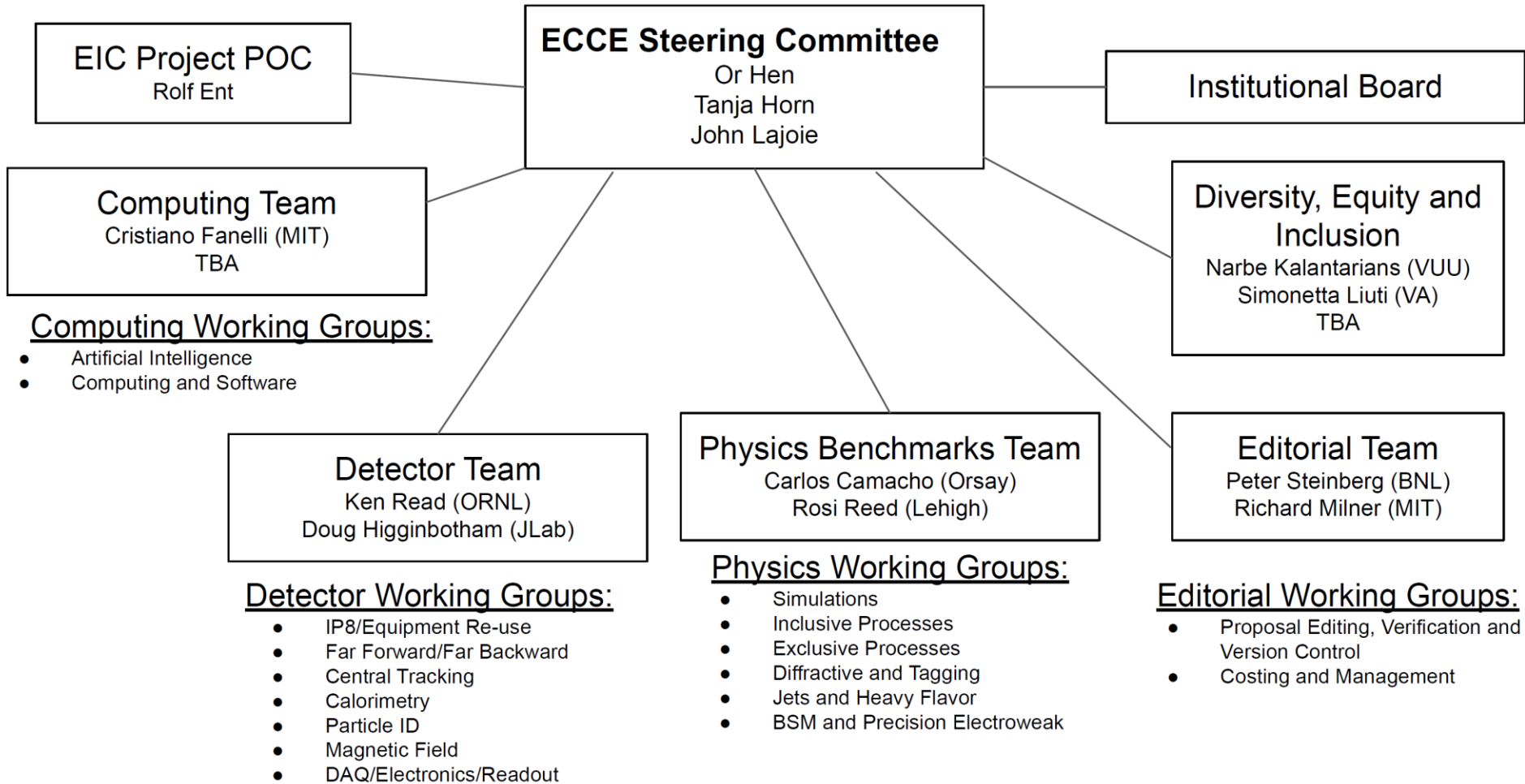
273 unique participant  
connections

# Workshop Structure

- Morning Session
  - Talks on the Yellow Report requirements, Previous studies
  - Q&A with EIC Project Management
  - Wisdom from past endeavors
- Afternoon Session
  - Talks on potential detector technologies for ECCE
  - 10 min contributed talks
- Next Steps (**IMPORTANT**)
  - Important discussion about forming an Institutional Board, working groups and the path to a proposal

|       |  |                       |
|-------|--|-----------------------|
| 09:00 | Introduction: What is ECCE? (15+5)   | John Lajoie           |
|       | EIC Physics and the Yellow Report (25+5)   | Dr. Her...            |
|       | EIC Detector Requirements (25+5)   | Tanja Horn            |
| 10:00 | EIC Detector w/BaBar Solenoid 2018 Study (25+5)  | Prof. Christine Adala |
|       | Coffee Break   |                       |
| 11:00 | EIC Project Q&A/Discussion (60)  | James Yeck et al.     |
| 12:00 | EIC Interaction Region Requirements and Constraints (25+5)   | Holger Witte          |
|       | How Large Projects Happen (25+5)   | Glenn Young           |
| 13:00 | Lunch Break  |                       |
|       | Tracking (20+5)  | Yulia Purielova       |
| 14:00 | Particle ID (20+5)   | Thomas Hennrich       |
|       | Calorimetry (20+5)   | Alexander Bazilevsky  |
| 15:00 | Far Forward Detectors (20+5)   | Dr. Alexander Jentsch |
|       | Far Backward Detectors (20+5)  | Barak Schmookler      |
|       | Coffee Break   |                       |
|       | The CORE Proposal (10)   | Charles Hyde          |
| 16:00 | 4m Silicon Hybrid Detector with Charged Particle Identification and Highest Position Resolution for an Experiment at EL...<br>Rachid Nouicer |                       |
|       | Studies of Forward Calorimetry in ECCE (10)  | Nicolas Schmidt       |
|       | All-Si Tracker (10)  | Reynier Cruz Torres   |
|       | EIC Silicon Consortium (10)  | Laura Gonnella et al. |
|       | EIC LGAD Consortium (10)   | Wei Li                |
|       | EIC Software EIC (10)  | Markus Diefenthaler   |
| 17:00 | Closeout and Next Steps (20+5)   | Richard Miller        |
|       | Discussion (35)  |                       |
| 18:00 |  |                       |

# ECCE Consortium structure

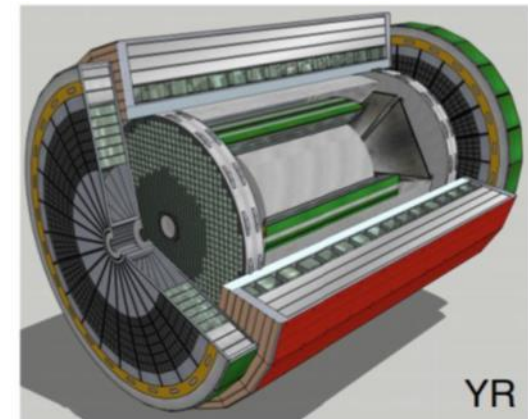


# ECCE Organization

- ❑ **Email lists:** available for subscription at <https://lists.bnl.gov/mailman/listinfo> :
  - ecce-eic-public-l: ECCE consortium public announcements
  - ecce-eic-ib-l: Institutional board announcements
  - ecce-eic-dei-l: Diversity, Equity and Inclusion Team discussion and announcements
  - ecce-eic-det-l: Detector Team discussion and announcements
  - ecce-eic-phys-l: Physics Benchmark Team discussion and announcements
  - ecce-eic-prop-l: Proposal Team discussion and announcements
- ❑ **Meetings:**
  - ECCE Indico being set up for workshop/meetings:  
<https://indico.bnl.gov/category/339/>
  - Anticipate frequent working group meetings, similar to YR activity
- ❑ **Documentation:**
  - Collection of information and results using common tools
- ❑ **Simulation tools:**
  - Received feedback from simulation experts from YR activity – anticipate decision soon

# What will ECCE look like

- Conceptually a lot like the reference detector
- Existing BaBar solenoid (1.5T), flux return and cradle



## Central Barrel Detector:

- ☐ Hadronic Calorimetry - possibly based on the existing sPHENIX magnet flux return.
- ☐ Electromagnetic Calorimetry
- ☐ Central Tracker
- ☐ Pre-shower

## Hadron Endcap

- ☐ Forward Calorimetry
- ☐ Particle ID
- ☐ Forward Tracking

## Lepton Endcap:

- ☐ Electromagnetic Calorimetry
- ☐ Hadronic Calorimeter
- ☐ Particle ID

Far Forward Detectors

Far Backward Detectors

Polarized Beam and polarimetry

Electronics

Computing

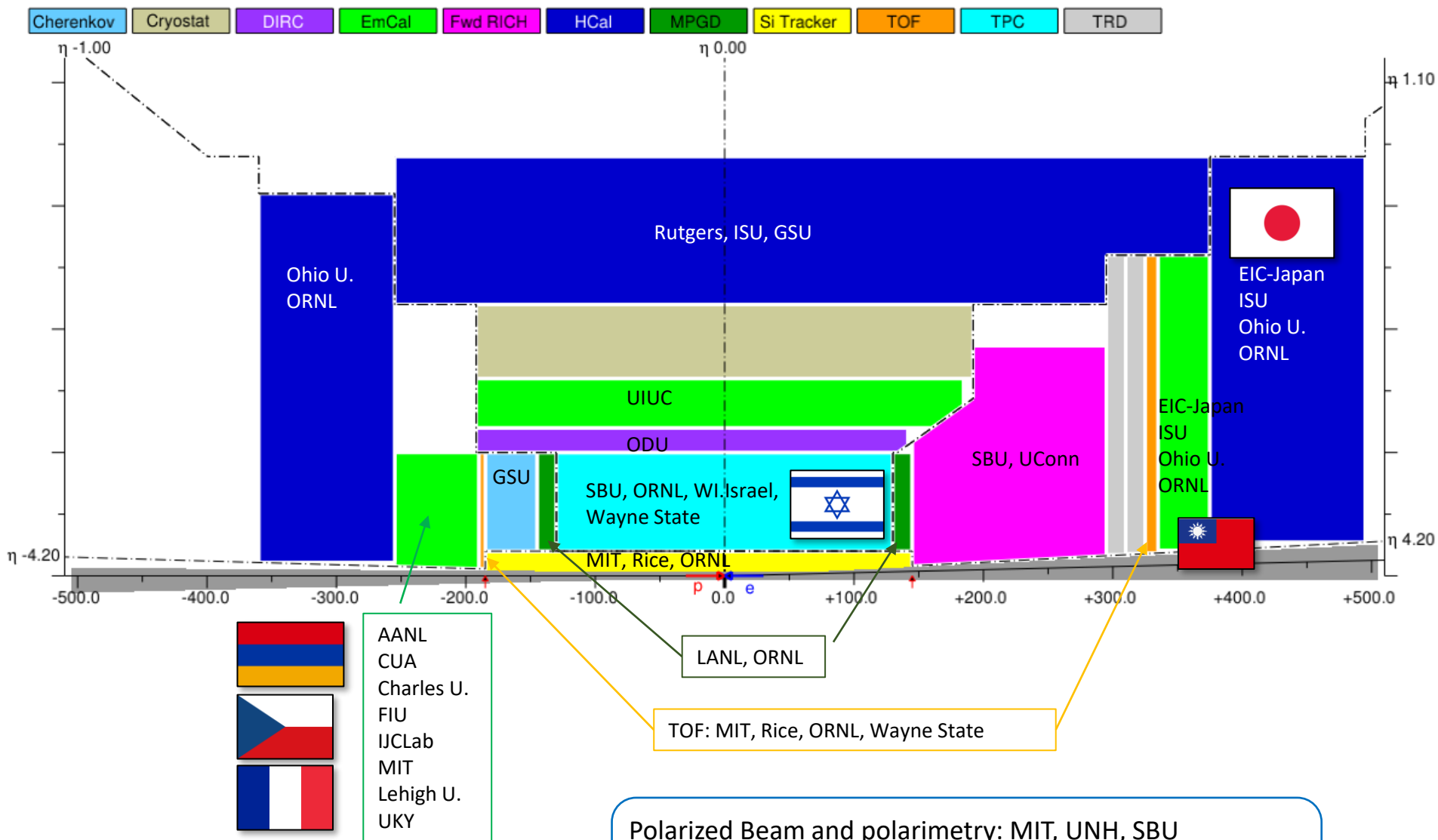
The EIC physics program can be accomplished with this field

| Parameter  | New Magnet        | BABAR/sPHENIX Magnet |
|--|-------------------|----------------------|
| Maximum Central Field (T)                                  | 3                 | 1.5                  |
| Coil length (mm)   | 3600              | 3512                 |
| Warm bore diameter (m)                                     | 3.2               | 2.8                  |
| Uniformity in tracking region<br>( $z = 0, r < 80$ cm) (%) | 3                 | 3                    |
| Conductor  | NbTi in Cu Matrix | Al stabilized NbTi   |
| Operating Temperature (K)                                  | 4.5               | 4.5                  |

**Table 11.1:** Summary of some of the main requirements of the EIC detector solenoid magnet.



# ECCE Central Detector - Overview



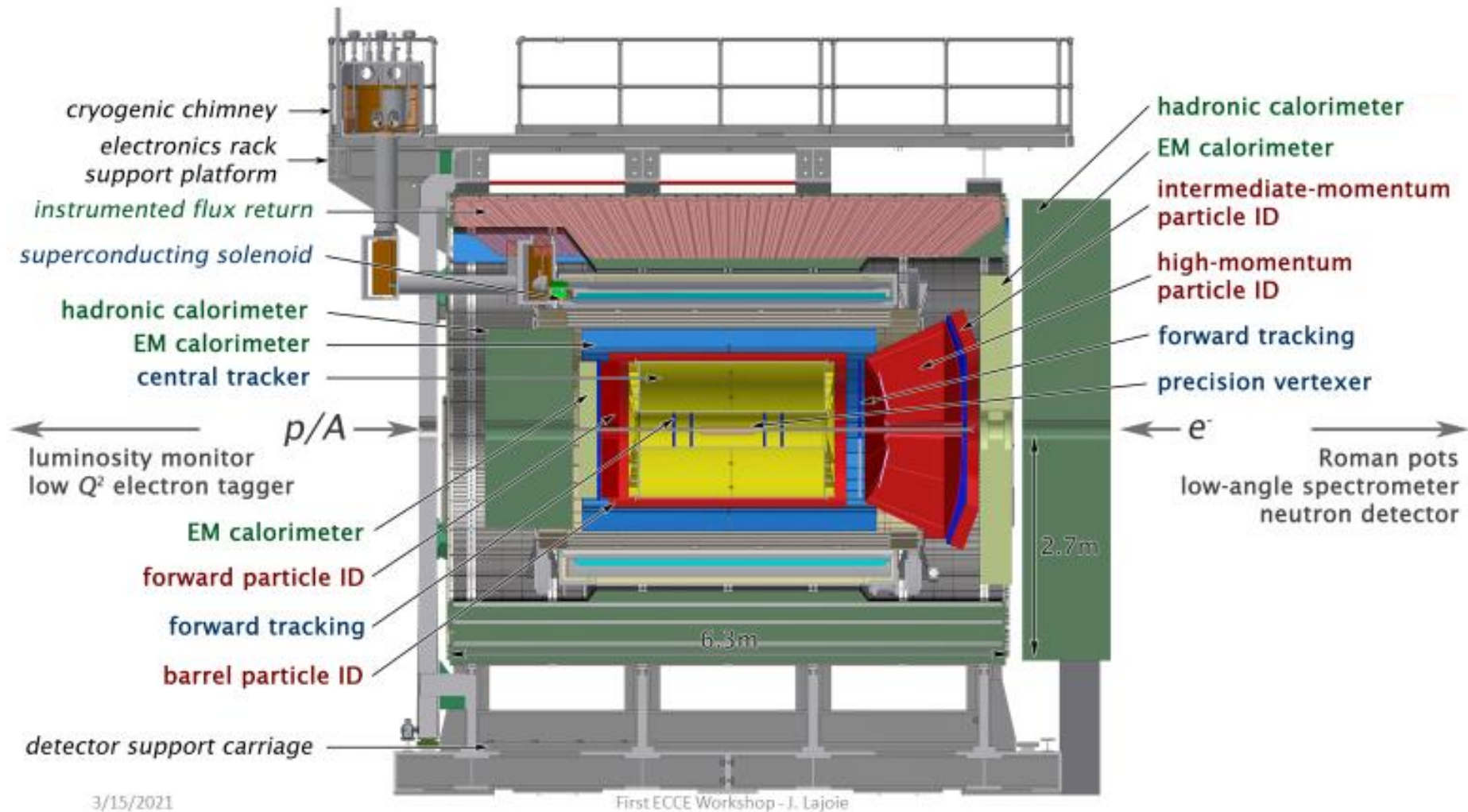
Polarized Beam and polarimetry: MIT, UNH, SBU

Electronics: Columbia, ORNL

DAQ/Trigger: ISU, CU Boulder, OU, ORNL, SBU, UConn, LLNL



# ECCE Central Detector – mechanical model



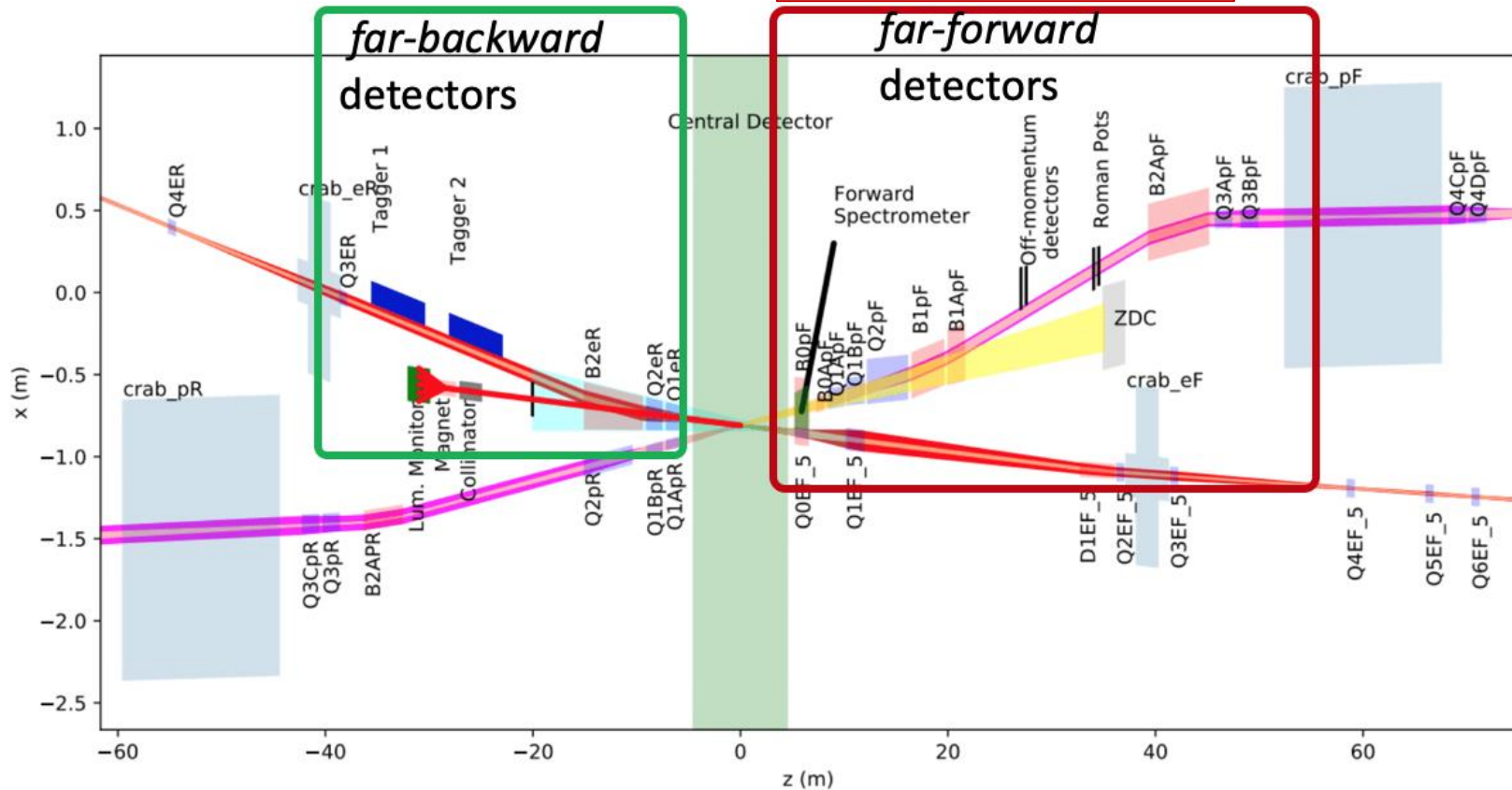
3/15/2021

# ECCE Overview Far Forward/Backward region



Glasgow U., ODU

BGU/Israel, MIT, ORNL, UIUC, IJLab-Orsay, EIC-Japan, TAU/Israel, UVA, GWU, MIT-BATES, HUIJ/Israel



# Example of Physics possible with ECCE: Spin

Major requirements:

- ☐ Precision calorimetry in lepton endcap
- ☐ PID in barrel

ECCE:

- ☐ High resolution calorimetry in lepton endcap
- ☐ PID in barrel
- ☐ PID in forward endcap enables also TMDs

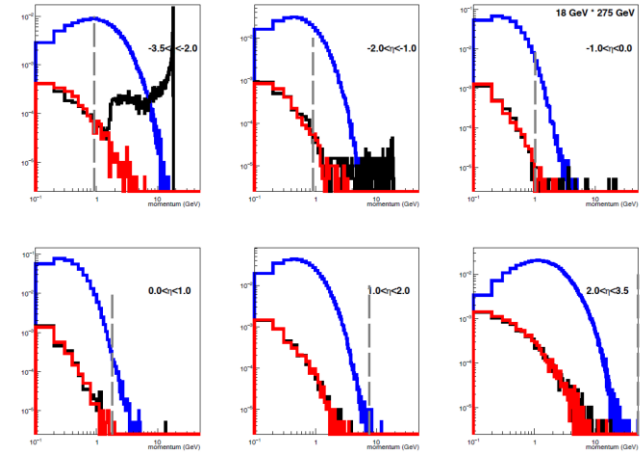
18x275 GeV

Electrons

Pions

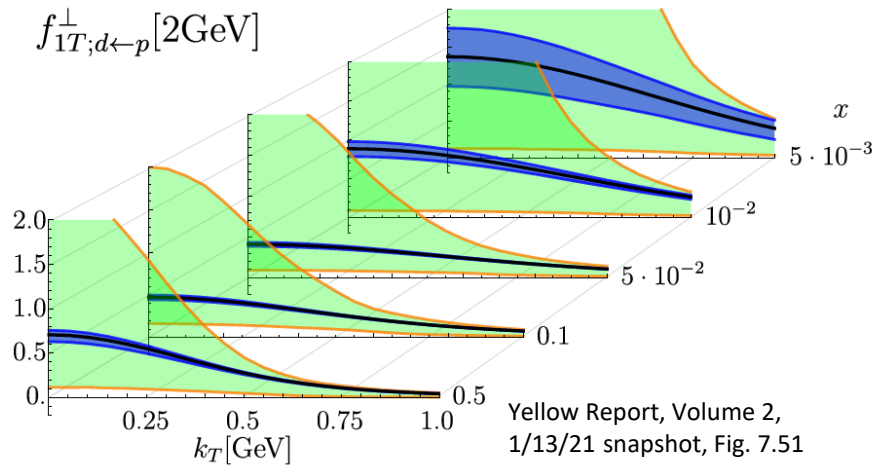
Positrons

Scattered Electron Background

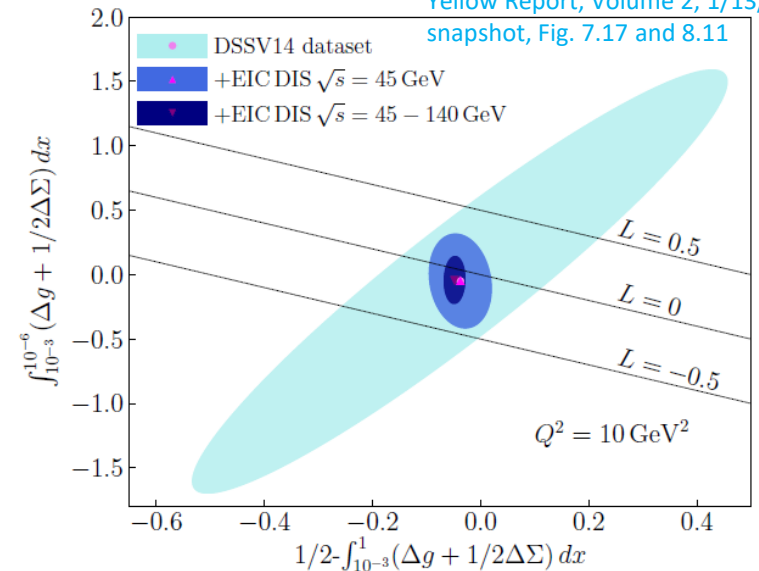


11/19/20

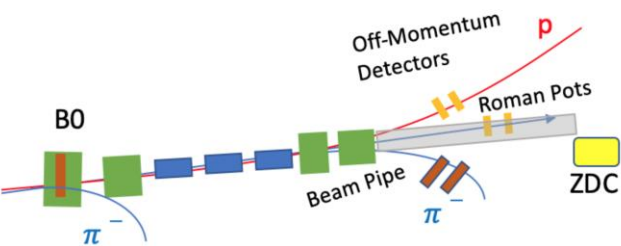
Yellow Report, Volume 2, 1/13/21  
snapshot, Fig. 7.17 and 8.11



Yellow Report, Volume 2,  
1/13/21 snapshot, Fig. 7.51

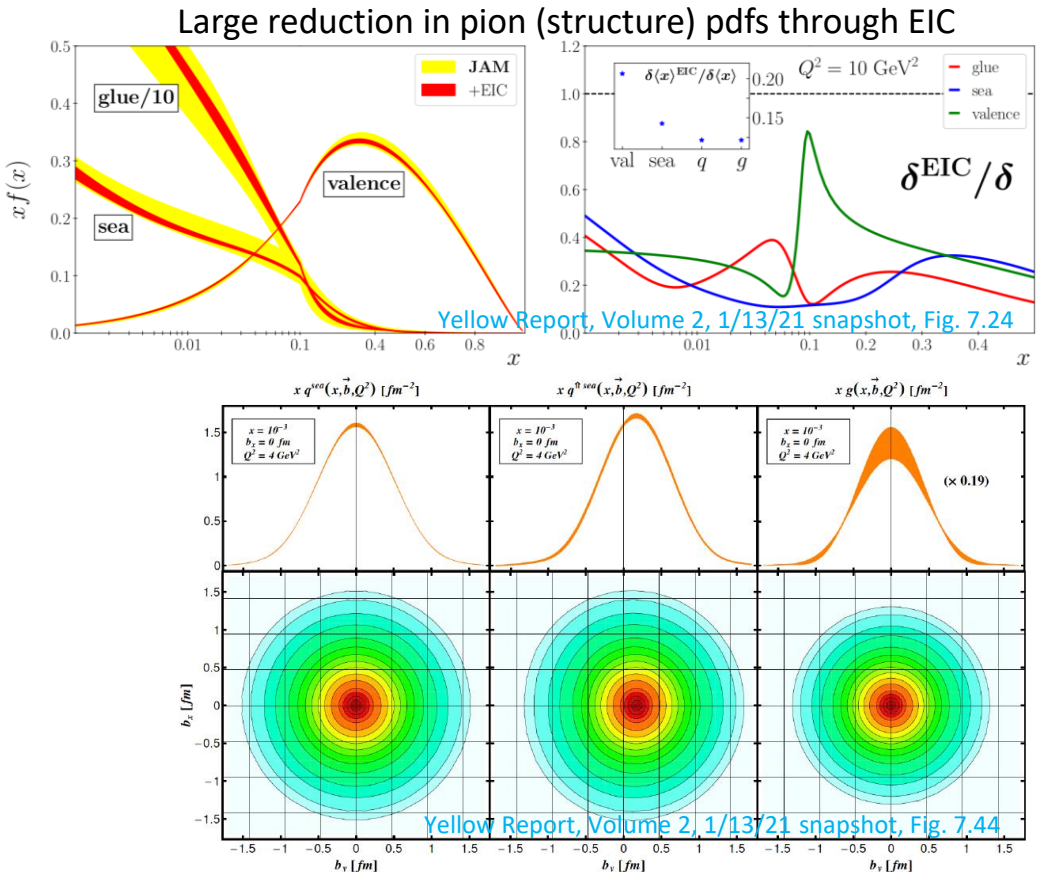


# Example of Physics possible with ECCE: Origin of Hadron Mass



## Major requirements

- ❑ Far Forward detection to tag n and  $\Lambda$  (or  $\Sigma^0$ ) (meson structure) and to tag p (for DVCS/3D).
- ❑ Scattered electron detection in electron endcap
- ❑ Good hadron endcap and far-forward calorimetry (goal: 35%/E, <50%/E acceptable)
- ❑ For pion form factor: pion in hadron endcap

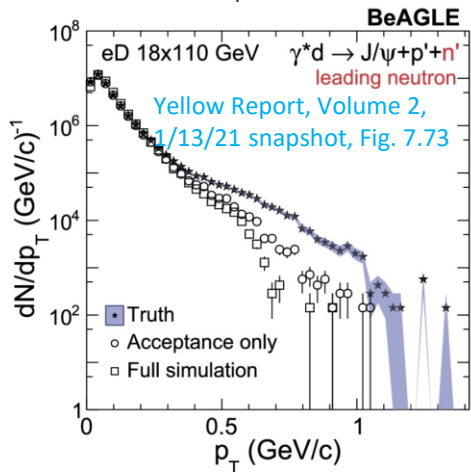
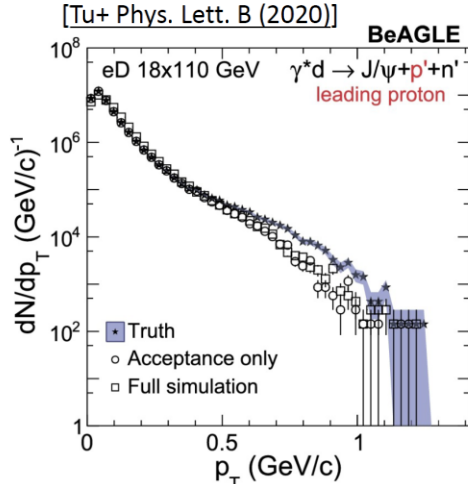


ECCE – physics reach enhanced in  $x_L$  and  $x_B$  with beam focus with dispersion – relevant for diffraction (e-p, e-A) and tagging (e-d, e-3He, etc), and exclusive measurements

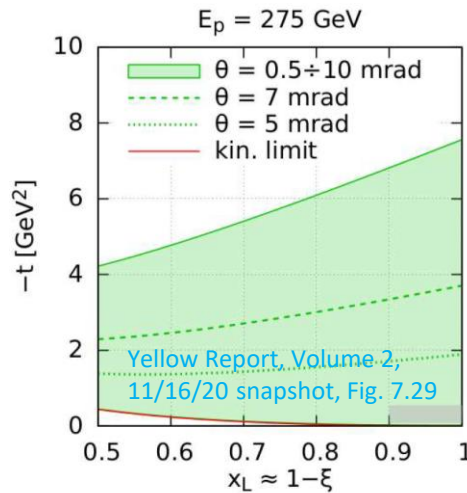
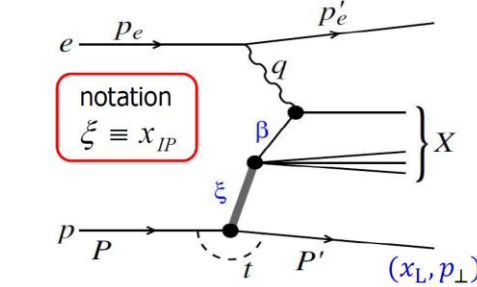
| # | Parameter   | EIC IR #1 | EIC IR #2    | Impact  |
|---|---|-----------|--------------|---|
| 8 | Minimum $\Delta(B\rho)/(B\rho)$ allowing for detection of $p_T = 0$ fragments | 0.1       | 0.003 – 0.01 | Beam focus with dispersion, reach in $x_L$ and $p_T$ resolution, reach in $x_B$ for exclusive processes |

# Example of Physics possible with ECCE: Nuclei

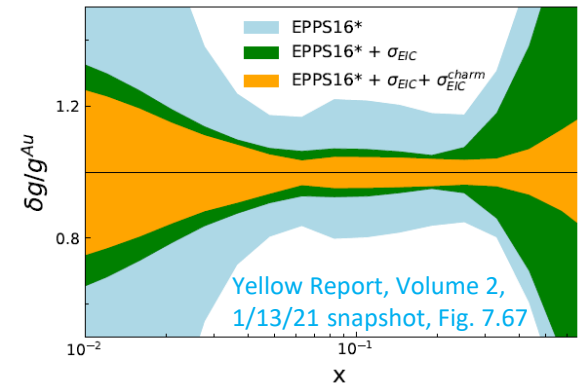
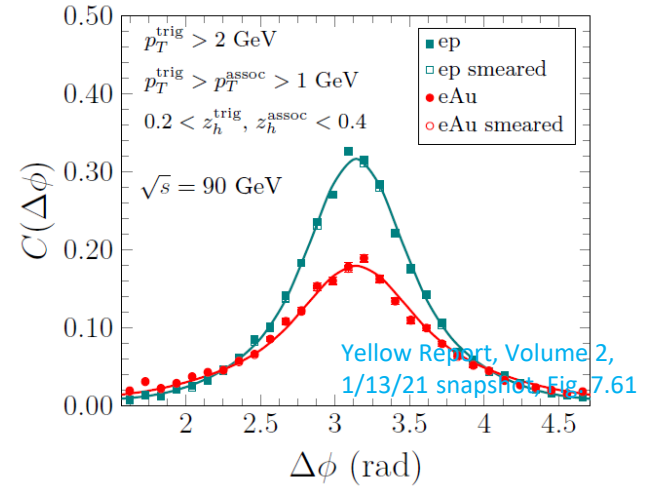
Incoherent diffractive J/ $\Psi$  production in e-d tagging



Inclusive diffraction in e-A



di-hadron azimuthal angle correlation, nuclear glue ratio through inclusive and open charm



ECCE – physics reach enhanced in  $x_L$  and  $x_B$  with beam focus with dispersion – relevant for diffraction (e-p, e-A) and tagging (e-d, e-3He, etc), and exclusive measurements

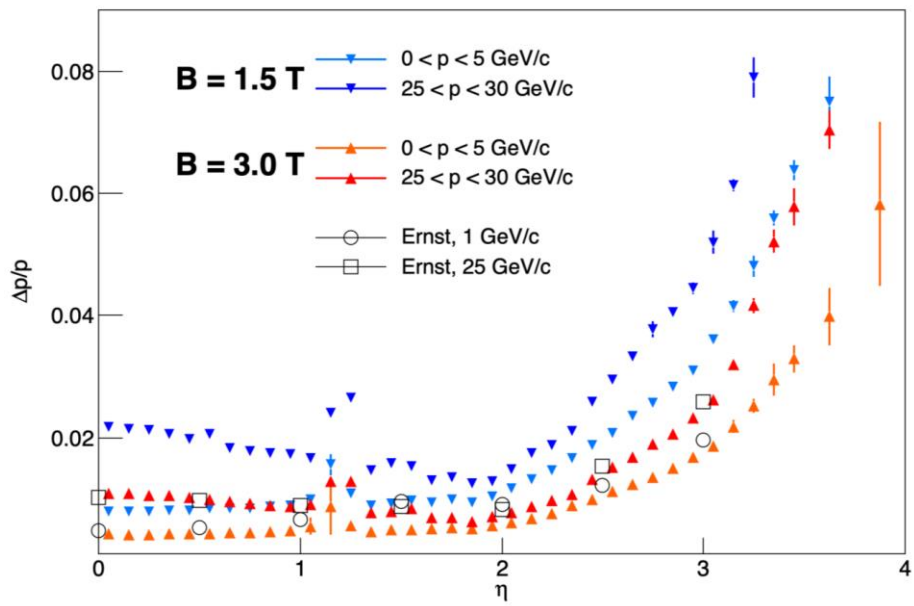


# Challenges with B=1.5T

Resolution in forward region  $\eta > 2.5$

- Jets and heavy flavor group requires higher resolution in forward hadron region.

Jets/HF WG ([https://wiki.bnl.gov/eicug/index.php/Yellow\\_Report\\_Physics\\_Jets-HF](https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Jets-HF))



Track Momentum Resolution

| Eta Range            | Default Resolution ( $\sigma P/P$ )% | Requested ( $\sigma P/P$ )% |
|----------------------|--------------------------------------|-----------------------------|
| $-3.5 < \eta < -2.5$ | $0.1\% \cdot P + 0.5\%$              | Same                        |
| $-2.5 < \eta < -2.0$ | $0.1\% \cdot P + 0.5\%$              | Same                        |
| $-2.0 < \eta < -1.0$ | $0.05\% \cdot P + 0.5\%$             | Same                        |
| $-1.0 < \eta < 1.0$  | $0.05\% \cdot P + 0.5\%$             | Same                        |
| $1.0 < \eta < 2.5$   | $0.05\% \cdot P + 1.0\%$             | Same                        |
| $2.5 < \eta < 3.5$   | $0.1\% \cdot P + 2.0\%$              | Same                        |

- However, lower field can also be useful in tagging and reconstruction of certain heavy mesons ( $D^*$ ) – resolution vs. acceptance/efficiency balance

| Pseudorapidity Range | Min $p_T$ (3T) [MeV/c] | Min $p_T$ (1.5T) [MeV/c] |
|----------------------|------------------------|--------------------------|
| $0.0 < \eta < 1.0$   | 400                    | 200                      |
| $1.0 < \eta < 1.5$   | 300                    | 150                      |
| $1.5 < \eta < 2.0$   | 160                    | 70                       |
| $2.0 < \eta < 2.5$   | 220                    | 130                      |
| $2.5 < \eta < 3.5$   | 150                    | 100                      |

# Solenoid bore diameter & Barrel Detector Space needs

|                                |   |
|--------------------------------|---|
| Tracking                       | all-Si maybe down to 50-60 cm,<br>Si + TPC = 80 cm                  |
| Tracking support structure     | 5 cm  |
| Hadron particle identification | DIRC only needs 10 cm,<br>RICH 50 cm but better for uniformity      |
| EM Calorimetry                 | 50 cm for high-resolution,<br>30 cm for less-resolution (or costly) |
| PID & EMCal support structure  | 10-15 cm likely enough  |

| Function                            | Minimum [cm] | Maximum [cm] | Minimum [cm]                           | Maximum [cm] |
|-------------------------------------|--------------|--------------|--|--------------|
| Tracking (includes<br>5 cm support) | All-Si       |              | Si + TPC                               |              |
|                                     | 65           |              | 85                                     |              |
| Hadron particle<br>identification   | RICH         |              | DIRC                                   |              |
|                                     | 50           |              | 10                                     |              |
| EM Calorimetry                      | 30           | 50           | High-Resolution to achieve $P < 2$ GeV |              |
|                                     |              |              | 50                                     |              |
| PID & EMCal<br>support structure    | 10           | 15           | 10                                     | 15           |
| Total                               | 145          | 165          | 155                                    | 160          |

Need to discuss the fit of all detectors in the existing magnet with bore 2.8 meter - will be a tour de force and it is possible some functionality has to give.



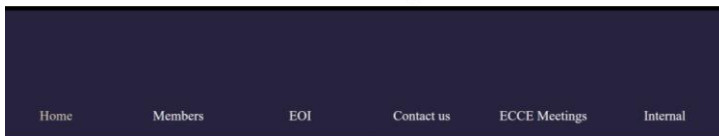
# Next steps

- ☐ Decide on simulations framework
- ☐ ECCE simulation workshop planned for March/April 2021
  - Preparation for full GEANT4 detectors simulations
  - Open to everyone interested
- ☐ Subsystem configuration
  - Tracking
  - PID
  - Etc.
- ☐ Subsystem simulations
- ☐ Specification of key physics processes and validation in ECCE layout
- ☐ Costing, R&D, etc.
- ☐ Collaboration structure
- ☐ Proposal writing, editing, submission (1 December 2021)

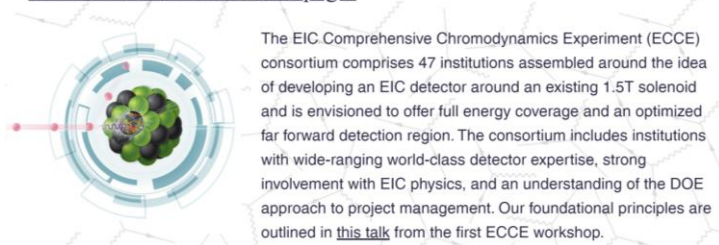
# Additional Information

❑ Web site including contact information: <https://www.ecce-eic.org/>

❑ Please contact us if interested in exploring this avenue



Welcome to the ECCE homepage!



We are open for all members of the EIC science community to join our effort. Please contact Or Hen ([hen@mit.edu](mailto:hen@mit.edu)), Tanja Horn ([hornt@cua.edu](mailto:hornt@cua.edu)), and/or John Lajoie ([lajoie@iastate.edu](mailto:lajoie@iastate.edu)) for details on how you can get involved!